geoconvention
Calgary • Canada • June 20-22 2022

Novel coverage assessment and decimation of a high-resolution 3D dataset

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Summary

CMP fold has been shown to be a limited and potentially misleading measure of seismic data acquisition quality (e.g. Lansley, 2004). As an alternative, here a Fresnel-based approach to 3D seismic coverage assessment is proposed and tested using an unusual decimation scheme. The decimated dataset is processed through a modern flow including 5D interpolation and PSTM, and while some expected degradation is observed relative to the full reference data, the decimated final image does not show footprint or character that might be predicted from the CMP fold map. The results suggest that given current processing tools, CMP fold criteria for seismic acquisition may have become not only limited in utility, but entirely irrelevant. If so, new tools for evaluation of seismic coverage are necessary.

Theory / Method

Fresnel-based seismic coverage has been used offshore for infill assessment for many years (e.g. Monk, 2009). This uses the increase in Fresnel zone size at farther offsets, and it should be noted that if this approach is valid, even at near offsets the Fresnel zone is never small enough to be approximated by a CMP. Instead, if illumination provided by Fresnel zones from all source-receiver pairs is adequate at all offset and azimuth ranges required for analysis of the target, and adequate SNR is gathered at all frequencies that are recoverable, then sufficient information has been gathered about the target to permit reconstruction of the wavefield.

This analysis was applied to an orthogonal high-resolution survey in the Athabasca region of northern Alberta, and proposed novel decimation scheme. The proposed decimation scheme has the appearance of a severe footprint in CMP coverage, with low/zero-fold bins in a ‘checkerboard’ pattern. With Fresnel-based coverage, however, very little footprint is expected at the target as near-offset Fresnel zone coverage is generally complete despite reduction in trace density to 25% of the original data.

Results, Observations, Conclusions

Both the decimation and the full dataset were reprocessed with the same conventional processing flow. In this test, true amplitudes / AVO compliance was not tested so all available processing tools could be brought to bear on improving both images. Since the decimation is based on an orthogonal 3D design, it was found that most tools could be applied readily. All steps were re-done independently on the two volumes. This includes static corrections and velocity analysis, which yielded surprisingly similar results. A notable exception was cross-spread noise attenuation, which required an intermediate interpolation step for the decimated volume due to the gaps in the source line and receiver line directions. After the cross-spread noise attenuation

was complete, the interpolated traces were deleted and only the decimated traces (with noise removed) were taken forward.

Prior to 5D interpolation and imaging, the decimated volume had higher remnant noise and resulted in somewhat lower frequency content, which is predictable given the significant reduction in trace density relative to the full volume. This also led, predictably, to a reduction in frequency content and resolution in the 5D interpolation result and final image. Efforts to benchmark 5D interpolation (e.g. Bayati and Trad, 2021; Stanton et al., 2012) have shown dropping greater than 30-50% of a dataset reduces the accuracy of the interpolated result, depending on method and input signal-to-noise ratio. Oilsands data tends to be high SNR, but this decimation example drops 75% of the traces, which was necessary to create the severe footprint for the test. Nonetheless, the decimated image is broadly very comparable to the full data image with continuous reflections and similar interpretable features at target depth. The severe footprint expected from the CMP fold is not apparent at any depth of interest.

Novel/Additive Information

A relatively similar distribution of CMP offset and azimuth in each bin is often stated as a requirement for successful seismic imaging, but in this decimation that is clearly violated. Over a third of the bins have single or zero fold and thus no distribution in offset or azimuth at all. Some manner of spatially averaged coverage is needed to predict the complete image that results from processing the decimated volume, and Fresnel based coverage is the best candidate to constrain the appropriate extent of that spatial averaging. Applying Fresnel based criteria for seismic data acquisition can lead to substantial cost reductions on land as it has in marine – the decimation here would have cost approximately half as much as the full dataset.

Acknowledgements

The authors wish to thank Brian Hargreaves and Aaron Stanton, and all contributors from Key Seismic who found innovative solutions to the problems posed by this unusual decimation. We also thank Parsons Chang for advice and review throughout the work.

References

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Monk, D.J.; 2009; Fresnel Zone Binning: Application to 3D seismic fold and coverage assessments; The Leading Edge; 28(3); pp288-295

Stanton, A., Kreimer, N., Bonar, D., Naghizadeh, M., and Sacchi, M.; 2012; A comparison of 5D reconstruction methods; SEG Annual Meeting Expanded Abstracts

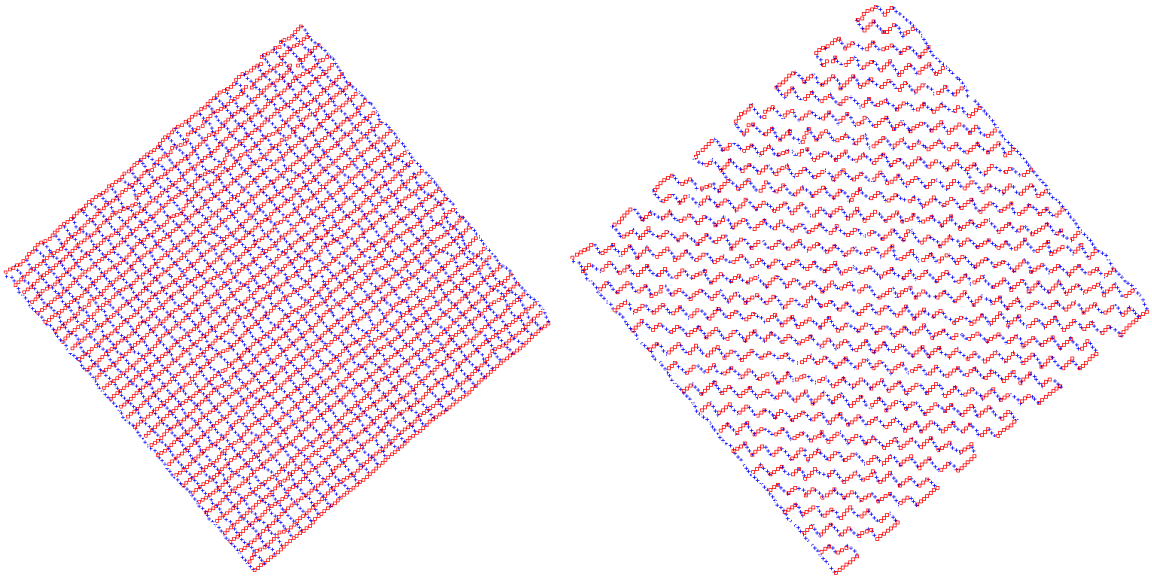

Figure 1. Left: Reference (Full) dataset. Line spacing 30m and stations spacing 10m for both sources and receivers. Right: Decimated dataset.

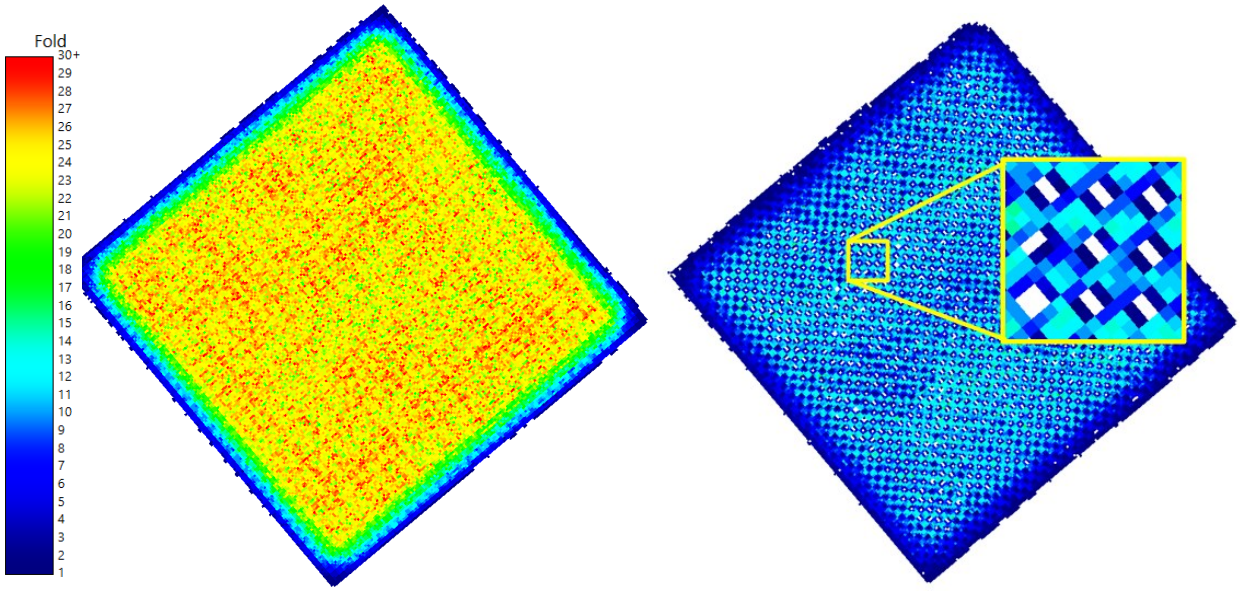

Figure 2. CMP fold in 5x5m bins for Full dataset (left) and Decimation (right)

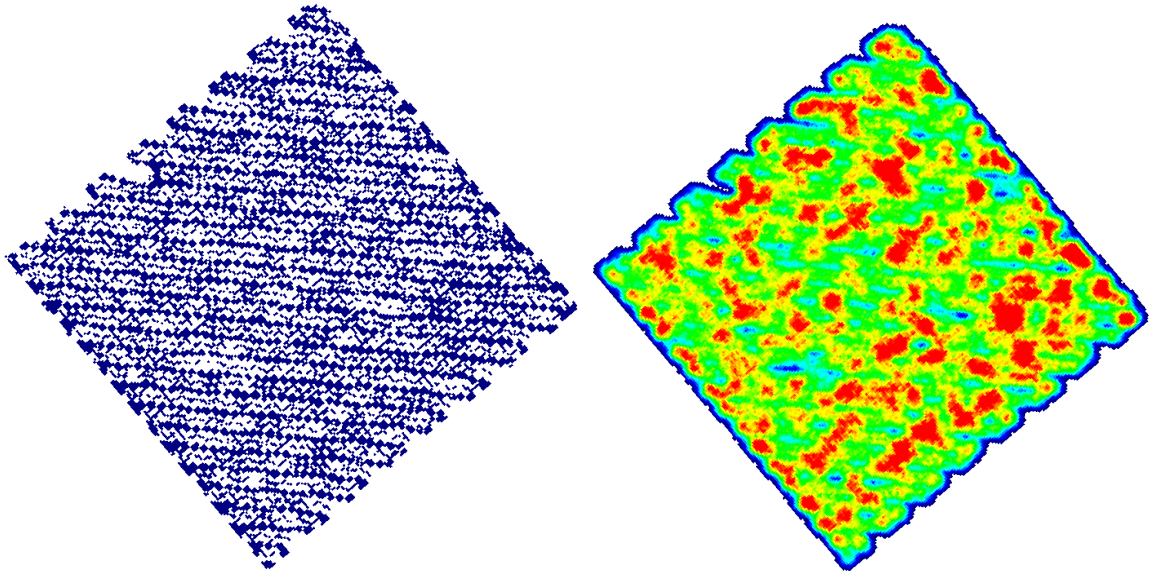

Figure 3. Near offset coverage for Decimated dataset. Left: CMP hits. Right: Fresnel-based coverage.

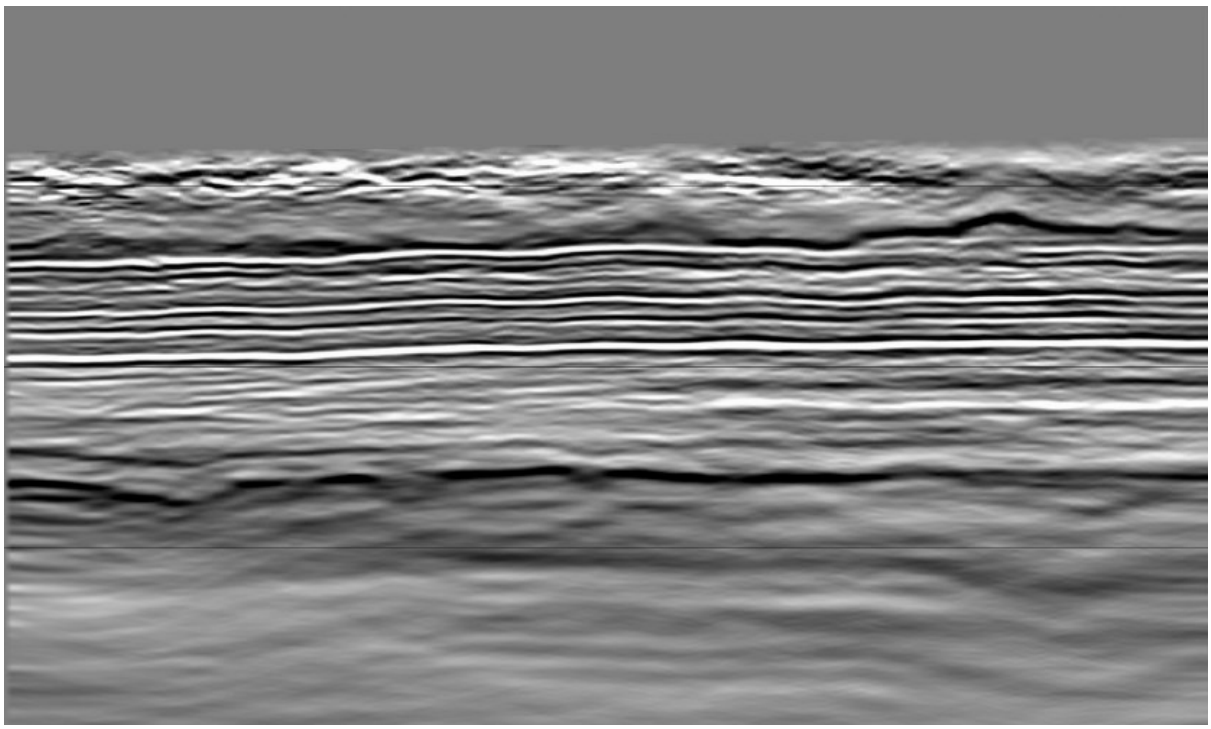

Figure 4. Reference (Full) dataset example inline from final 5D interpolated PSTM volume.

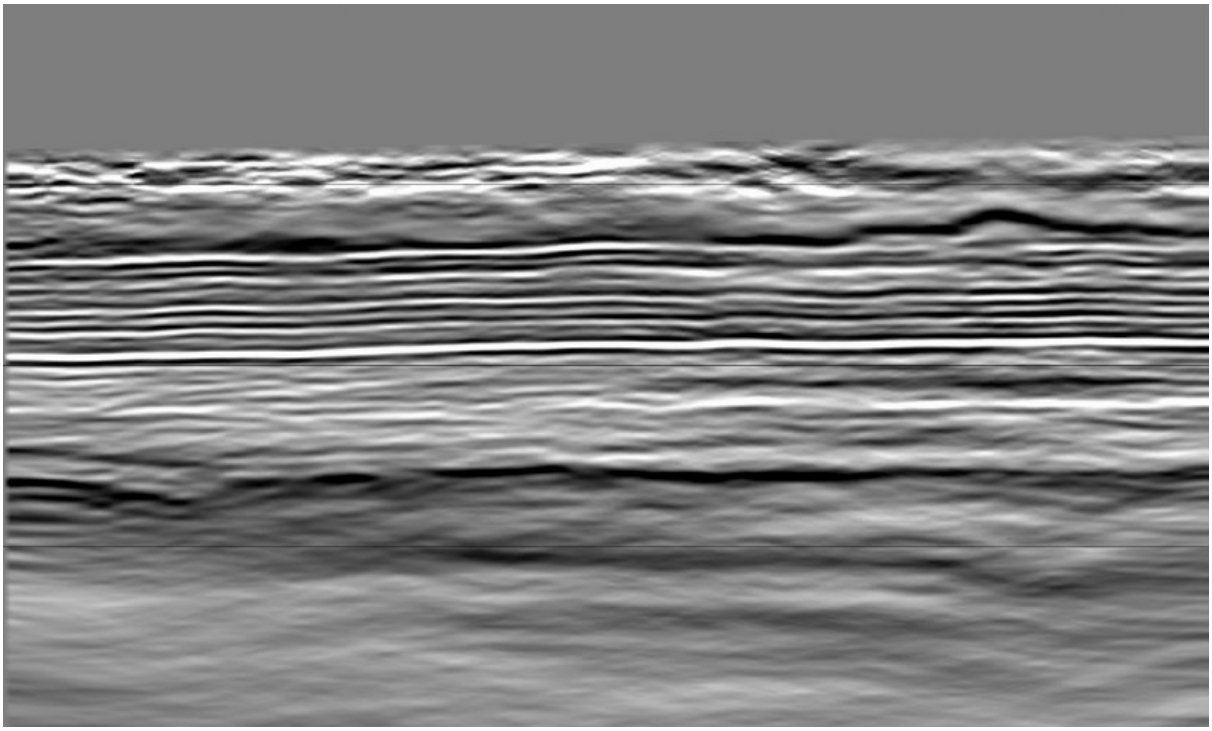

Figure 5. Decimated dataset example inline from final 5D interpolated PSTM volume.

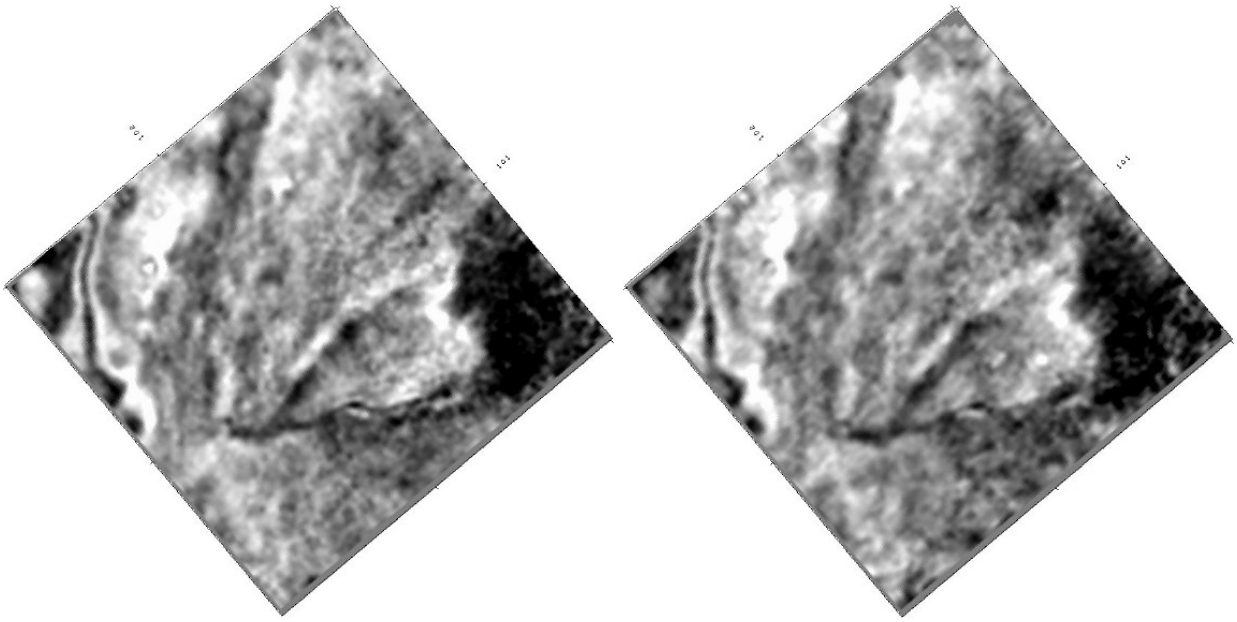

Figure 6. Timeslice in the target reservoir from Reference (Full) dataset (left) and Decimation (right).